ICMB23

2nd International Conference on Moisture in Buildings (ICMB23), online, 3-4 July 2023

The effect of brick properties on hygrothermal performance of solid walls

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Abstract

To construct buildings of the future that are both energy-efficient and moisture-resilient, it is critical to have an in-depth understanding of the varying characteristics of brick properties. This study sampled eight brick-cores taken from solid walled homes across the UK, to investigate the impact of thermal conductivity and hygrothermal parameters on U-values and moisture accumulation. Modelled U-values of uninsulated solid walls, in this sample, ranged between 1.6 and 2.6 W/m^{2}K, with 6 of 8 the homes having surface condensation risks. There was even greater variability found in the moisture content in inner brickwork when simulated in WUFI, between 0.1 to 5.8 %, indicating some bricks are at significantly higher risk of moisture accumulation.
Peer-review under the responsibility of the organizing committee of the ICMB23.

Keywords: Hygrothermal modelling; Brick properties; Building Regulations; Moisture accumulation; U-values.

1. Introduction/Background

It is well understood that bricks, from which historic solid walled homes in the UK were built, have different material properties based on the bespoke production methods and locally available raw materials. These differences make it difficult to accurately predict the energy consumption and moisture risk of houses. Energy Performance Certificates (EPCs) assume solid walls have a U-value of 1.7 W/m^{2}K, but in-situ testing has measured much variety in solid walls [1, 2]. The aim of this study is to investigate how the measured brick properties affect heat transfer and moisture content of solid external walls. This will be accomplished by comparing thermal conductivity and hygrothermal parameters, obtained from specialist material laboratory testing on the bricks, and comparing the results with appropriate default book values.

2. Methodology

The samples used were obtained throughout the UK: Leeds (17BG), Maltby (56TR), Stoke on Trent (LC01), Coalville (SJ01), Bedford (SJ02), London (SJ03) and Loughborough (57AD). A single brick core, measuring 100mm in diameter, was extracted from the external leaf of each house. The measured brick thermal conductivities were compared with book values in CIBSE Guide A [3]. These informed the U-values for each wall - 110mm outer brickwork, 10mm air/mortar gap, 110mm inner brickwork and 10mm gypsum plaster. TRISCO version 14.0w was used to assess U-values and surface condensation risk [4] and WUFI Pro version 6.6 [5] for moisture accumulation. Each brick core's measured hygrothermal parameters (density, porosity, specific heat capacity, diffusion resistance factor, reference water content and free water saturation) were entered into WUFI. The range of these parameters is significant; for example, 56TR (1.1 kg/m^3) has the lowest reference water content, while LC01 (117 kg/m^3) holds the highest. However, when assessing diffusion resistance factor, WUFI extruded brick (9.5) becomes the lowest and SJ02 (137.1) records the highest. In the case of four of the walls, in-situ U-values were obtained using the ISO standard procedure [6] to compare against the simulated values.

3. Results

The average simulated U-value, shown in Figure 1, was 2.1 W/m^{2}K and ranged between 1.6 to 2.6 W/m^{2}K. CIBSE guide A book values have an average of 1.7 W/m^{2}K and range between 1.4 to 2.0 W/m^{2}K. 5 out of 8 homes had predicted U-values beyond the CIBSE range, suggesting that solid walls have the potential to have much higher heat loss than predictions. Further analysis suggests internal surface condensation risks (temperature factor <0.75) were present in 6 out of the 8 uninsulated walls, indicating that surface condensation is likely to occur on uninsulated walls with a higher U-value. However also shown in Figure 1 are in-situ measured U-values, which indicate U-values may not have been as high as models predicted.

Figure 2 highlights that some bricks have substantially more moisture accumulation than others, specifically LC01, which was a common "fletton brick". LC01 had an average of 5.80% moisture content in the inner brickwork, and SJ01 had an average of 1.8%. These values were much higher than both other bricks in this study, and WUFI book values, all of which were <1% moisture content. LC01 has highest reference water content input, which may contribute to moisture accumulation.

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 DOI: 10.14293/ICMB230018

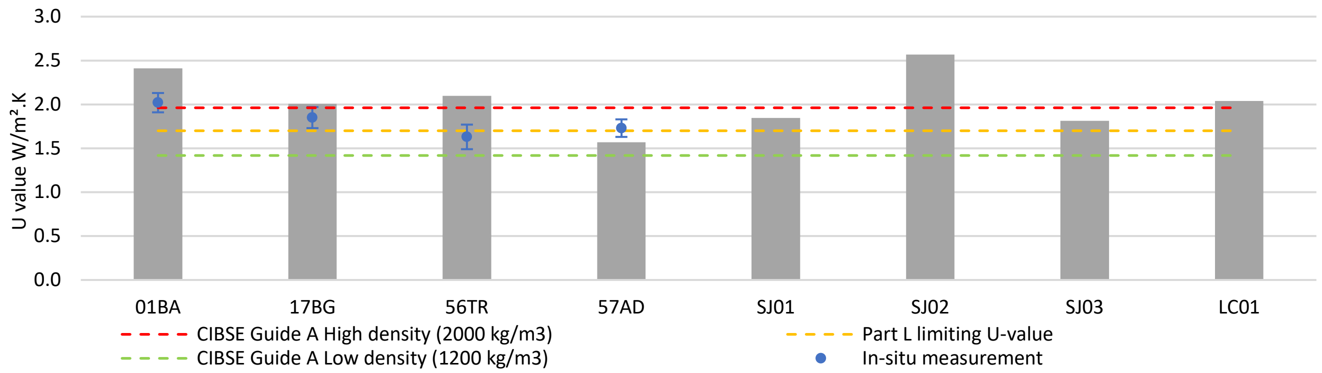

Figure 1. Pre-retrofit U-values (W/m^{2}K) of measured samples (grey bars) compared to book values and in-situ measurements (error bars show uncertainty)

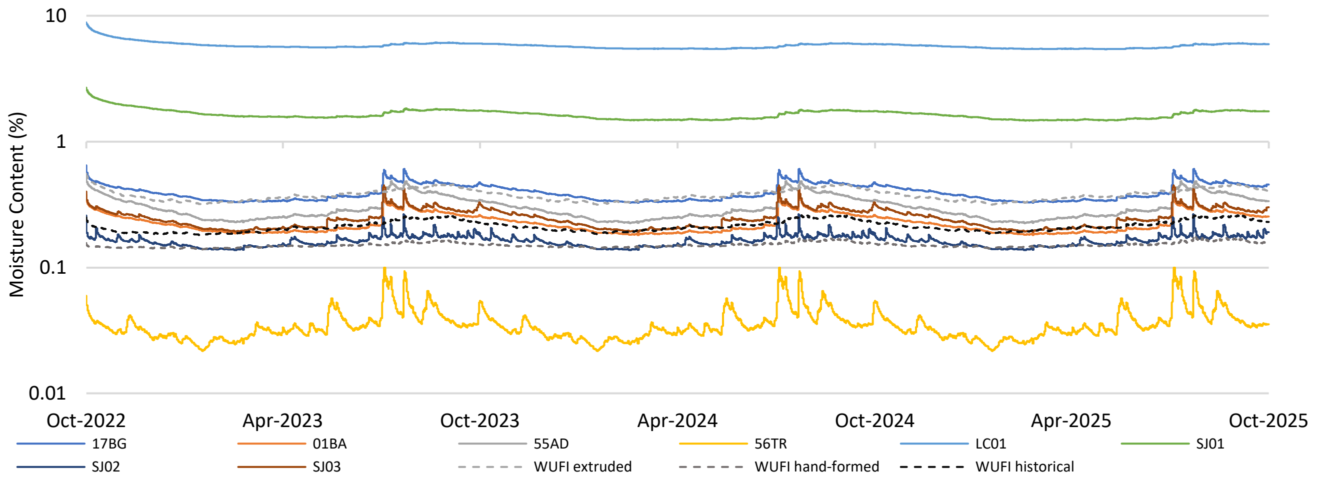

Figure 2. Percentage of moisture content in inner brickwork of measured samples compared to book values (in logarithmic scale)

4. Discussion

Most uninsulated solid walls had higher simulated U-values than EPCs predict, and large variability in U-values between walls. When retrofitting solid walls, a target U-value of 0.3 W/m²K is set by the Building Regulations for England and Wales [7]. Applying 100 mm of mineral wool EWI to the homes in TRISCO software predicts that the variability of U-values diminishes to between 0.3 to 0.32 W/m²K; thus, despite the variability in heat loss for uninsulated solid walls, their retrofits solution may be the same. The findings also show a large variation in hygrothermal parameters, which can significantly affect inner brickwork percentage of moisture content. This assessment cannot confirm the existence of moisture risk; hygrothermal assessments (e.g., timber rot or dew point evaluation) were out of scope for this study, but it confirms that different homes, based on their local area brick type, may be more at risk than homes in other areas which do not have the same brick types.

5. Conclusion

Heat transfer and moisture accumulation is significantly impacted by brick properties. Variability in uninsulated solid wall U-values has implications for national carbon modelling of the UK housing stock, and predicting retrofit savings for individual homes. The range in moisture content of the inner brickwork was very large, and worthy of more investigation. Future work will include evaluation of how insulation installation impact hygrothermal performance of brickwork.

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